other places is not only directly disproved, but is quite unnecessary in order to explain the sudden disappearance of the Great Northern Sea-Cow from the shores where it was first discovered.

I think it will be admitted that we have succeeded in materially strengthening Sauer's assertion, that the Rytina was exterminated in 1768, and that the above is a fair exposé of the causes which led to its final extirpation. It was simply due to man's greed, and he accomplished it within the short time of twenty-seven years.

THE MATERIALS OF THE APPALACHIANS.

BY E. W. CLAYPOLE.

(Concluded from page 962.)

The Four Great Sandstones of Pennsylvania.

IN the former part of this paper I dwelt on the fact of the existence of several thick sandstones and quartz conglomerates in the massive palæozoic deposits of Pennsylvania. I further showed that these rocks indicate a supply of quartz far greater than could be furnished from any existing source; and, thirdly, that the nature of this quartz is such that the only known origin for it is the quartz-ledges of the South Mountains. Hence I inferred the former extension of these strata over a greater extent of country than at present.

In this second part I propose to try and give a more definite shape to this conclusion, and to at least suggest where and when this palæozoic land existed.

Excluding, for various reasons which it is not necessary here to mention, the Potsdam Sandstone, there remain four great sheets of sandstone, more or less conglomeratic, in the immensely thick palæozoic deposits of the Eastern States. Between them there lie massive, softer deposits of shale and limestone. In descending order these beds are as follows, omitting all minor and insignificant layers:

		Feet.
	Shale, coal, sandstone	Variable.
4	Sandstone and pebbles (Pottsville Conglomerate)	1500
	Shale (Mauch Chunk)	1500
3	Sandstone and pebbles (Pocono Conglomerate)	2000
	Sandstone and pebbles (Catskill Sandstone)	6000

		Feet.
	Shale and limestone (Devonian)	4000
2	Sandstone and pebbles (Oriskany Sandstone)	300
	Shale and limestone (Lower Helderberg, etc.)	300
1	Sandstone and pebbles (Medina, Oneida, etc.)	1500
	Shale and limestone (Trenton, etc.)	5000
	Sandstone (Potsdam)	400

Here are four vast beds of sandstone, all more or less conglomeratic, lying between thick masses of softer rocks. In ascending order they are the Medina, the Oriskany, the Catskill-Pocono, and the Pottsville. They vary in hardness, in thickness, and in coarseness, but they all agree in being composed of almost nothing but quartz in the form of pebbles and of sand.

Now, we are quite safe at the outset in asserting that these four great sandstones, with their alternating shales, represent as many changes in the conditions of deposition. The geographical arrangement of land and water that allowed the deposition of shale would prevent that of sandstone. Results so different argue different causes. Regarding the origin of the shales I do not now propose to inquire, and will therefore dismiss them without further notice, and refer only to the four great sandstones already mentioned.

It is obvious that each of these implies the destruction of an equal amount of rock elsewhere. They were not made from nothing. Inch by inch and pound by pound they and their pebbles represent and measure the rock whence they were hewn. So vast an accumulation of quartz, therefore, implies an equally large quarry from which it was obtained. But no such quarry exists; it has entirely disappeared.

Again, these four sandstones in succession imply not one but four quarries, and the consent of geologists is universal that these quarries must have been in the East; that this sand and these pebbles have travelled to the West and the Northwest.

I am inclined, therefore, to read in these four sandstones a record of changes which the eastern part of the country underwent during the palæozoic era. Reasoning back from the effect to its cause, I think we may see in them a history of what was occurring elsewhere during their formation.

Where, then, shall we seek the Eastern quarry of quartz-rock from which the massive Medina Sandstone was derived? It

seems to me that in this great conglomerate mass we have a record of a lost quartz-ridge or reef that existed in Middle Silurian days, but which long ago disappeared,—a reef of rock like that which now forms the ledges of the South Mountains; a ridge large and enduring enough to furnish all the sand and pebbles required, though the Medina is, in some places, two thousand feet thick.

Nor is the existence of such a lost ridge along the Atlantic sea-board altogether imaginary. We know that in later days a force has acted in the same region that was fully capable of producing such a result; and we have no reason to assume that the tangential pressure which at the end of the palæozoic era crumpled the crust and raised the Appalachian arches acted then for the first time. The grand catastrophe which shaped our Eastern States and closed the palæozoic era in North America may have been not its first, but its final, manifestation, and may have been preceded by others of equal, or even of greater, intensity. It is by no means unlikely that the same force that raised the Allegheny Mountain arches also raised, in Mid-Silurian days, a similar arch of the hard, semi-crystalline rocks like those of the South Mountains, from whose wreckage the Medina Sandstone was made. As it rose it was torn down by the waves, its quartz dispersed, and a new rock formed at a lower level.

A time of rest ensued. The deposition of quartz ceased and the Upper Silurian rocks were formed. But the resting stage came to an end and the earth-force again manifested itself. New crumplings set in and a new ridge was elevated, which we may call the Oriskany Ridge, as from its material the Oriskany Sandstone was probably formed. This, though thin when compared with the massive Medina, covers an equal or a greater extent of country, and in material the two can scarcely be distinguished.

Rest again ensued, and the formation and deposition of sand and pebbles again ceased. The huge beds of the Lower and Middle Devonian were formed, and meanwhile the pressure was accumulating for another thrust.

At last it came. The long pent-up force overcame the resistance. Another time of disturbance set in. Another part of the Archæan area was brought within the denuding force of the waves. Sand and pebbles were again formed, and the thickest

quartz-bed of the whole series was laid down. Judging by its effects this was the most extensive disturbance of the four. It formed a bed of sandstone reaching in some places a thickness of seven thousand feet, for the Catskill and the Pocono united sometimes surpass even these enormous figures. This implies immense erosion elsewhere, and the inference seems quite just that this Catskill-Pocono Ridge formed a conspicuous or an enduring feature in the Upper Devonian landscape.

But it disappeared and a time of inaction followed, marked by the deposition of numerous soft beds on the eastern sea-board and in the midland basin. These are now the Lower Carboniferous Rocks. Again the compressing force overcame its resistance and a fourth ridge arose, whose destruction in due course furnished the material of the Pottsville Conglomerate, underlying the Coal-Measures. The manufacture of quartz-sand and of pebbles again began, and a sheet of this material was spread over Western Pennsylvania, West Virginia, and Ohio, gradually diminishing in thickness and in size as it recedes from the parent reef. On this, when the stock of quartz was exhausted, were laid down the coal-beds, with all their intermediate limestones, shales, and sandstones.

Such, as I read it, was the history in brief of these four sandstones. I have omitted all details, all minor beds, and have touched only the great features of the story. Four acts in the drama are now complete, and the fifth and last follows in due course.

No trace remains of the four elevations above mentioned except the four monumental sandstones built up from their remains. But the case is different with the last. This was the great earth-thrust that occurred at the close of the Carboniferous period. Then the suspended force again came into action, and the newly-formed coal-beds were crushed and crumpled into the arches and troughs in which their remains now lie. Of this latest catastrophe abundant traces remain. The ridges then formed have not yet disappeared, and all the ranges of Pennsylvania, with the possible exception of the South Mountains, date their beginning to that event. This last act in the drama is one of the great facts in American geology. It is the greatest epoch in the history of the continent. The Appalachian Revolution closed the Palæozoic era and lifted North America above the waves of the ancient sea.

We need, therefore, only extend backward a known process to explain the origin of these four sandstones. We can in imagination see a series of ridges rising one beyond another in time gone by on what is now Eastern Pennsylvania. We see these ridges destroyed as, or after, they arose, and we see their wreckage forming new strata at a lower level. Extinct mountains, we may call them, which have passed away and left no trace on the face of the earth save the four great sandstones which form their monuments.

The wide plains of Eastern Pennsylvania were the standing-ground of these ridges. An extension of the quartzy strata of the South Mountains over this district where the mica-schists of the Archæan are now exposed, the successive crumpling of these strata and their subsequent erosion, complete the picture. Abundant material was obtainable, for we must be careful not to limit the area to its present size. Crumpling causes compression, and the site of Philadelphia must have then been much farther from that of Harrisburg than it now is.[1] The Archæan terranes east of the South Mountains were then deeply buried beneath later deposits since removed. Each successive area of crumpling from east to west became compressed beyond all further compression, and then added itself to the compressor, thus aiding to shove forward the adjoining area just as layer after layer of snow is added in front of a snow-plough until the resistance becomes great enough to stop the engine.

In the consideration of this subject the geologist is often puzzled to find a transporting force sufficient to distribute this sand and these pebbles over so great an area. From the ridges whence they were derived they have been strewn over the country to the westward for five hundred miles, in sheets of remarkable evenness, gradually thinning out as the distance from the quarry increases. The Oriskany is especially remarkable in this respect. It extends over the whole area above named, and over parts of New York, Maryland, and West Virginia, forming a bed of almost unbroken continuity, but seldom exceeding two hundred or three hundred feet in thickness. To what power can we attribute the formation of so thin and yet so broad a sheet?

Without dogmatizing on this difficult subject, there is one

[1] See American Naturalist for March, 1885.

suggestion which I wish to make. It may be of some use in explaining the phenomena, and it may not. I am disposed to attribute it to the tide, whose forced wave, sweeping every day over the successive ridges or through the successive archipelagoes which I have described, tore away the rocks and swept the fragments westward, rolling them over and over against one another until they were ground to pebbles and to sand. The tide-wave reaches the bottom of the deepest water, and is not a mere superficial current. Its motion is incessant, twice a day, and not occasional as that of the storm-wave. Finally, its direction in this region was westward, and it is a fact of no little significance, in this connection, that, so far as we can determine, all the material of these four sandstones has travelled westward.

These considerations united induce me to believe that the tide-wave was the chief agent in their formation; that, rolling, as it did, every twelve hours from the East into the midland ocean of North America, through the successive archipelagoes or reefs which I have here attempted to describe, it acted as a grinding and transporting engine of transcendent power to fashion and to carry the sand and pebbles of which our great conglomerates consist.

There is nothing, so far as I am aware, in the rocks that is incompatible with these views. It is well known that the conglomerates are thicker and coarser in the East than in the West, and that there also pebbles of slate and other softer minerals are more abundant. Only the very hardest material—the quartz—could survive the wear and tear of so long and so rough a journey, and accordingly in the West this material constitutes the whole mass of the rock.

One other point should be at least alluded to. Recent researches have rendered it probable that this great grinding engine, this tide-wave, was more powerful then than now; but on this I do not care to insist. Sir Robert Ball's immense six-hundred-foot tide-wave must, I think, be relegated to a much earlier date. Yet the theory is entitled to whatever advantage may be derived from the greater tides of palæozoic time.

Should the suggestions here made and the views here advanced, regarding the origin and formation of the Conglomerates of Pennsylvania, prove to be of any value, they may indirectly bear on the moot question of the antiquity of the Atlantic

Ocean; for, if the transportation of the pebbles and sand was really due to the tide, it would indicate the existence of an Atlantic basin in pre-palæozoic days, from which the forced wave flowed over or through these successive reefs or ledges into the midland basin.

THE PERISSODACTYLA.

BY E. D. COPE.

(Concluded from page 1007.)

THE CHALICOTHERIIDÆ had numerous representatives during Eocene time, and a few species of Chalicotherium extended into Miocene time. The boundaries which separate the family from the Lophiodontidæ on the one hand and the Menodontidæ on the other are not always easy to determine. From the former the symmetrically-developed external V's of the superior molars and the double V's of the inferior molars distinguish it; yet in Pachynolophus the anterior cingular cusp produces a part of the

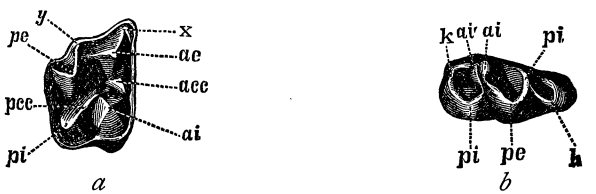

FIG. 24. *Lambdotherium popoagicum* Cope, molar teeth, natural size; from Wind River Eocene of Wyoming. From Wortman, after Cope. Fig. *a*, second superior molar; *b*, last inferior molar. *ae* and *pe*, anterior and posterior external V's; *y*, intermediate external rib; *x*, anterior external angle; *pi* and *ai*, anterior and posterior internal tubercles; *acc* and *pcc*, anterior and posterior intermediate tubercles; *h*, heel.

asymmetry found in the Lophiodontidæ. The character of the double inner cusps of the superior premolars, which distinguishes the Menodontidæ, is only found in the last premolar in Diplacodon of the latter, while a trace of the additional cusp of this tooth is found in the Chalicotheroid Nestoritherium.

In using the following table it must be borne in mind that the structure of the feet has not been determined in several of the genera: